Ocean Circulation (and Tide) Models

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OUTLINE

- applications
- atmospheric vs oceanic models
- differences between shallow and deep ocean
- what you need to know about the model you’re using
- what’s available from NAVO

Why worry about currents?

- Search and rescue
- Mine drift
- SDV and swimmer operations
- Ship routing
- Oil Spills
- Dispersal of chemical and biological weapons
- Turbidity
- Interaction with surface waves

Littoral Oceanography

Mission Planning Process
Essential Elements of Information (EEI)

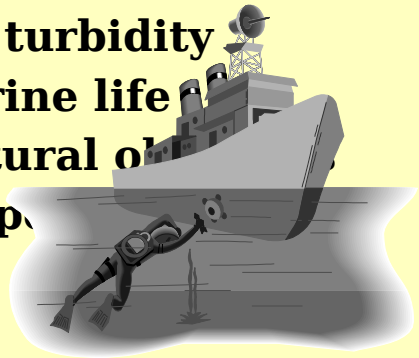
Meteorological characteristics in the area of operations t
be favorable to or limit the successful execution of a NSW

Meteorological EEI

- Wind direction and speed up to 30kft
- Sky condition (precip/cloud cover)
- Air temp up to 30kft(Icing)
- Weather extremes
- % RH
- Local effects on WX (winds/lows)
- Presence/effect of sunspots/ electrical interference
- Presence/effect of fog/mist
- Tabular data for:
  - Sunrise/set
  - Moonrise/set
  - Moon Phase/% Illum.
- Heat Index/wind-chill

Hydrographic EEI

- Water temperature/ thermocline
- Currents speed, direction & schedule
- Tide range, direction and schedule
- Bioluminescence
- Water depth/clarity
- Bottom composition
- Coastal gradient
- Surf and water turbidity
- Dangerous marine life
- Submerged natural ob
- Pollution transp
- Land albedo
- Trafficability
- Riverine conditions



Source: Patrol Leader's Handbook XL 00

Oceanic vs Atmospheric Models

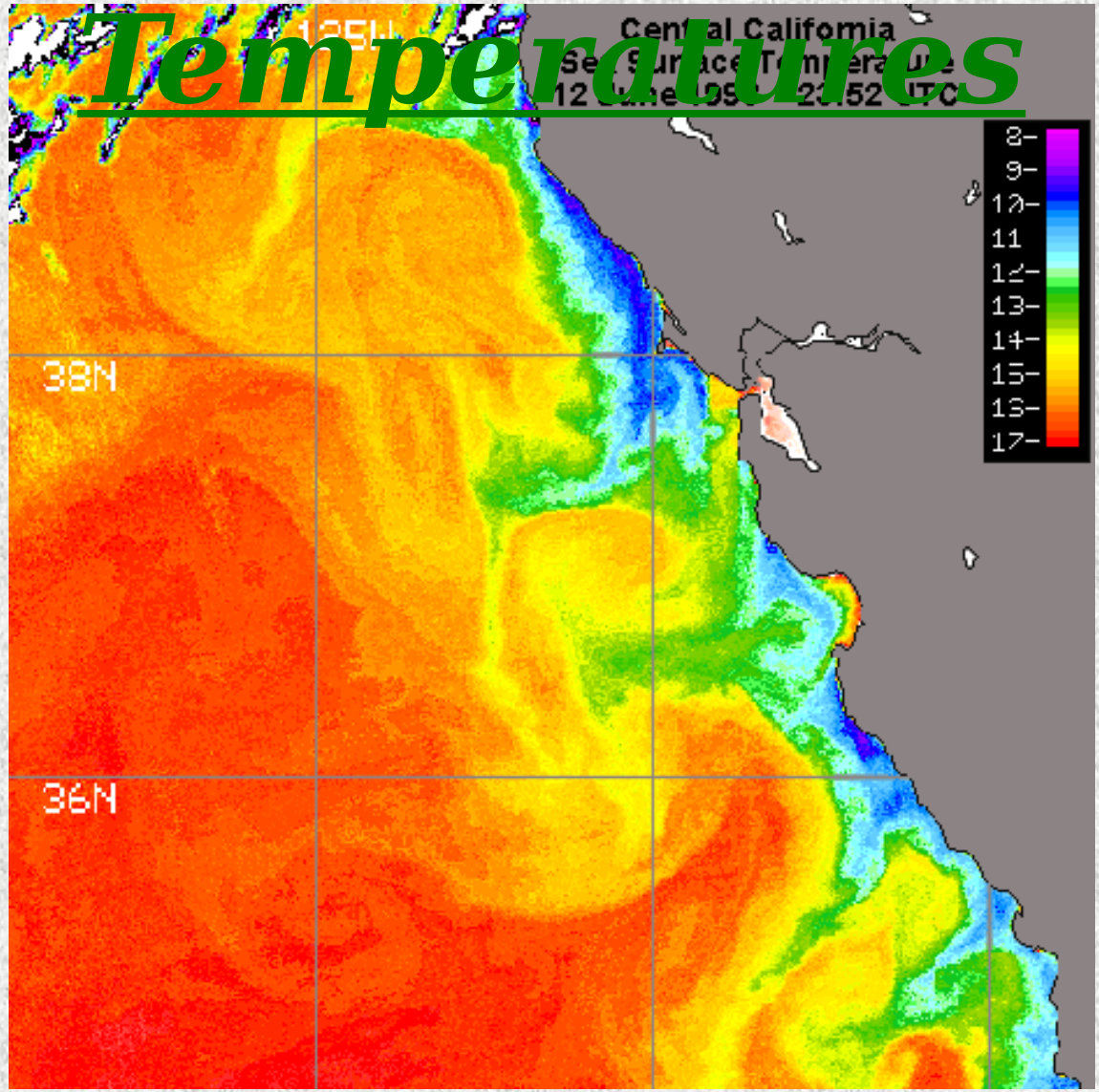
- Temp, Salinity vs Temp, Rel. Hum.
- Way fewer observations in ocean
- Ocean more viscous - longer spin-up time
- Even in global model, have to deal with boundaries - i.e. land

Differences between Shallow and Deep Ocean

- More temporal and spatial variability: due to river run-off, land-sea breezes, proximity to high energy boundary currents (more so near WBCs, but also EBCs), coastal upwelling. May go from well-mixed to stratified over short distances.

Littoral
Oceanography

Satellite Sea Surface Temperatures



- Topographic effects: topographic steering (includes wave refraction at high frequency, or fast, end of spectrum and vorticity effects at low frequency, or slow, end), bottom friction
- Coastal boundary: comes in through continuity equation, no flow through coast.

What you need to know about the model you're using

- **Physics**: geostrophic, barotropic vs baroclinic, mixed layer, primitive equation…
- **Forcing**: density gradients, tides, wind, heat flux
- **Initialization**: data analysis, previous run, climo
- **Boundary conditions / nesting**
- **Spatial resolution**: horizontal and vertical
- **Temporal resolution**
- **Grid system**: finite element, finite difference
- **Vertical coordinate**: z, σ, ρ
- **Topography**

What’s available from NAVO?

- MODAS
- POM
- SWAFS
- SDOM
- NLOM
- AdCirc
- PC-Tides
- GFMPL - SAR

MODAS

Modular Ocean Data Assimilation System

Analysis system that uses optimal interpolation to incorporate MC-SSTs, sea surface height (SSH) from satellite altimetry, temperature and salinity data from profiles and fixed or drifting buoys, with climatological data to produce 3-dimensional temperature and salinity fields. Three-dimensional sound velocity fields, and associated acoustic parameters, and **geostrophic velocity** fields, are derived from the temperature and salinity fields. In water depths greater than 2000 m, geostrophic velocities are referenced to 2000 m. In water depths less than 2000 m, geostrophic velocities are referenced to the bottom, i.e. it is assumed that there is no horizontal pressure gradient at

MODAS Issues

- Differences between v1.6 run at regional centers and v2.1 run at NAVO
- What to use for first-guess field
- Data compaction
- Spatial resolution
- Type and weighting of satellite and in-situ data used (for ex., SSH not used in Med. and some other areas.)
- Output variables and formats
- Regional center has some control over items in green and also can add value by providing quality control

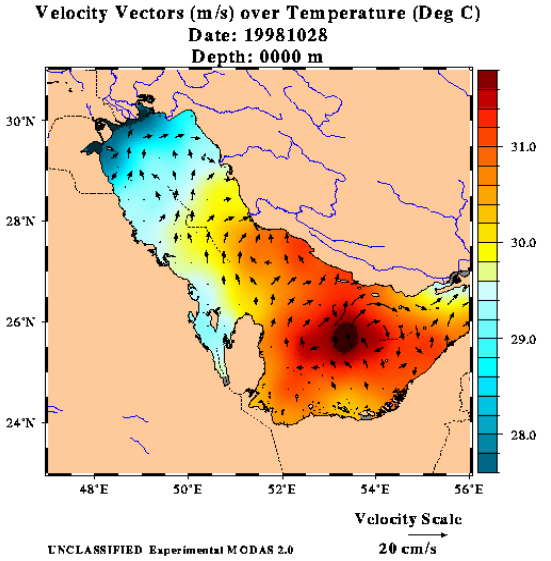
MODAS 2.1 OUTPUT PRODUCTS

```
ZNR UUUUU
O 281742Z OCT 98
MSGID/NAVO/GRIDFLD/1504/OCT
PROD/OCEANMET/281742Z4/OCT/000/1OF1
GRID/3100N4/04700E1/0M/133/97/34/0.068DEG/0.083DEG/VAR/03
NARR/UNCL prgars MODAS2 TEMPERATURE 98301 981028
              8
    5  133    1   97
   97     -2.027655125      1.865198374
:I8:U98:D9.875420ZYXVUTSSRR.Q.POMMKJIHG.E.DCC.B:JA:DB:DC.DEE
LMMRW027CHJQW2556795ZUTMEBLYGQ5CTXJL0JLX1JO7WQ0CVE82O9ZCQZG7WPXY5OD0
20.210847855
:KB:YA.B.CDDEGGHHIIJJKLMMOOPQRSTTUUVVWXX.YZ01223344.5:D677668:M9:E8:
```

```
JJXX 28108 0000/ 12930 04800 88888 00275 MODAS
JJXX 28108 0000/ 13000 04800 88888 00276 MODAS
JJXX 28108 0000/ 12830 04830 88888 00292 03291 08290 MODAS
JJXX 28108 0000/ 12900 04830 88888 00283 03282 08281 13280 MODAS
JJXX 28108 0000/ 12930 04830 88888 00279  03279  08279 MODAS
JJXX 28108 0000/ 12800 04900 88888 00294 03293 MODAS
JJXX 28108 0000/ 12830 04900 88888 00293 03292 08292 13290 18286 MODAS
JJXX 28108 0000/ 12900 04900 88888 00291 03291 08290 13289 18288 MODAS
JJXX 28108 0000/ 12930 04900 88888 00286 03285 08285 13286 18285 MODAS
```

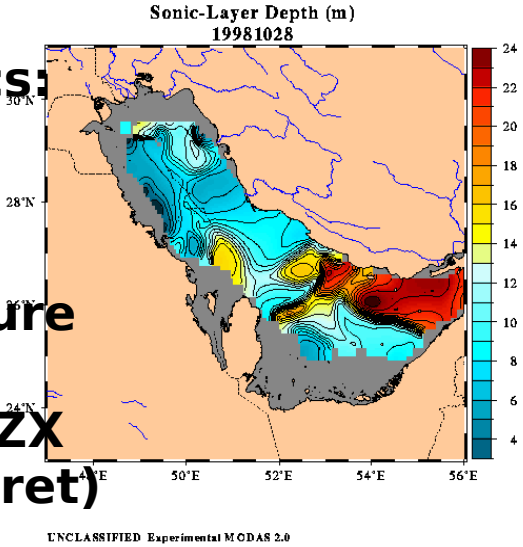
Text/Binary/Message Files:

- Byte-Encoded & EOF-Compact
Temperature/SV (also pushed t
centers, facilities & ships at se
- JJXX/JJYY/KKXX SyntheticBTs
- OVLY2 of Physical/Acoustic parameters
- NetCDF of Temperature/SV/Sa
- ARCVIEW Format

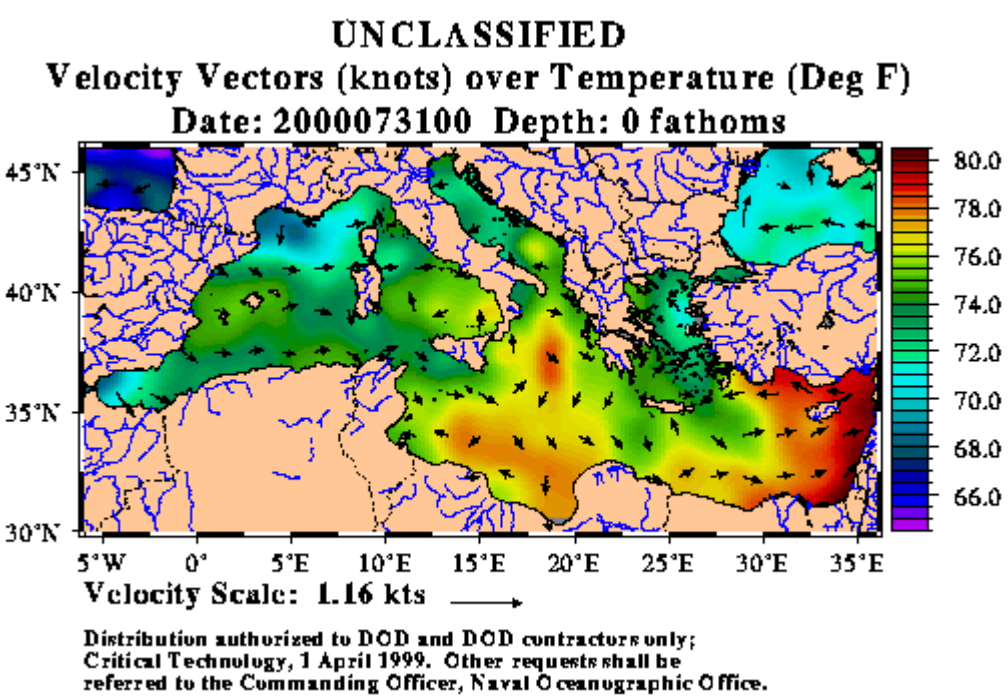


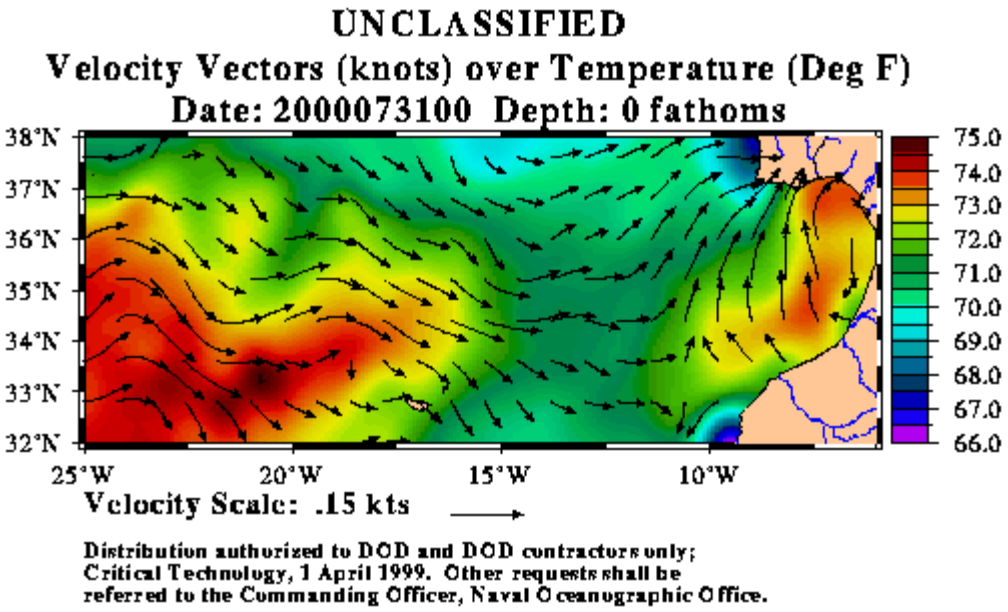
Physical/Acoustic Graphics:

- Temperature Contours at Depth
- Currents over Temperature at Depth
- DSCA, SSCA, MLD, SLD, ZX
- Observations Chart (Secret)



MODAS


UNCLASSIFIED
Velocity Vectors (knots) over Temperature (Deg F)
Date: 2000073100 Depth: 0 fathoms
45°N
40°N
35°N
30°N
5°W
0°
5°E
10°E
15°E
20°E
25°E
30°E
35°E
80.0
78.0
76.0
74.0
72.0
70.0
68.0
66.0
Velocity Scale: 1.16 kts
Distribution authorized to DOD and DOD contractors only;
Critical Technology, 1 April 1999. Other requests shall be
referred to the Commanding Officer, Naval Oceanographic Office.


UNCLASSIFIED
Velocity Vectors (knots) over Temperature (Deg F)
Date: 2000073100 Depth: 0 fathoms
38°N
37°N
36°N
35°N
34°N
33°N
32°N
25°W
20°W
15°W
10°W
75.0
74.0
73.0
72.0
71.0
70.0
69.0
68.0
67.0
66.0
Velocity Scale: .15 kts
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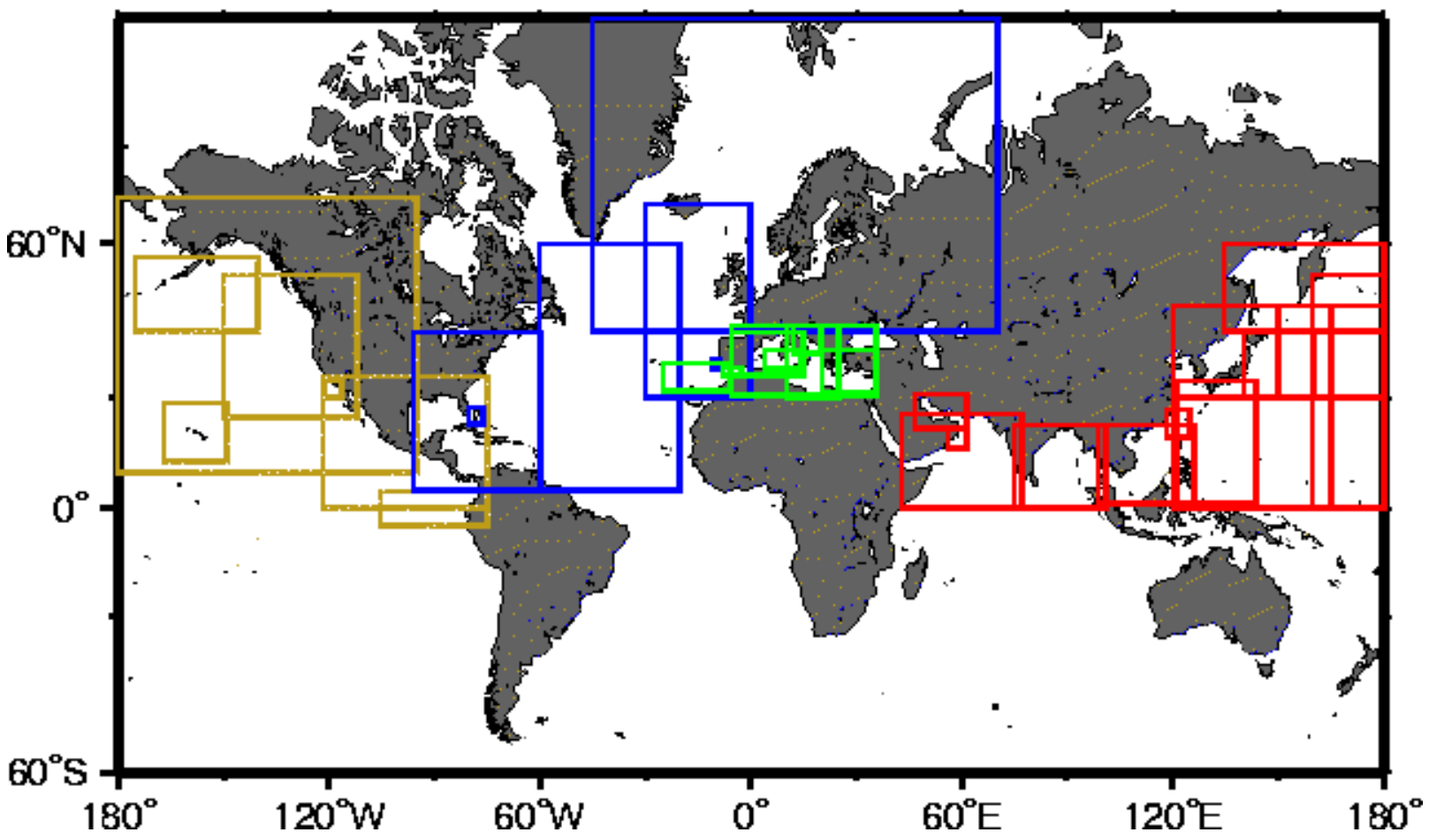
referred to the Commanding Officer, Naval Oceanographic Office.


MODAS Areas by Center AOR
60°N
0°
60°S
180°
120°W
60°W
0°
60°E
120°E
180°

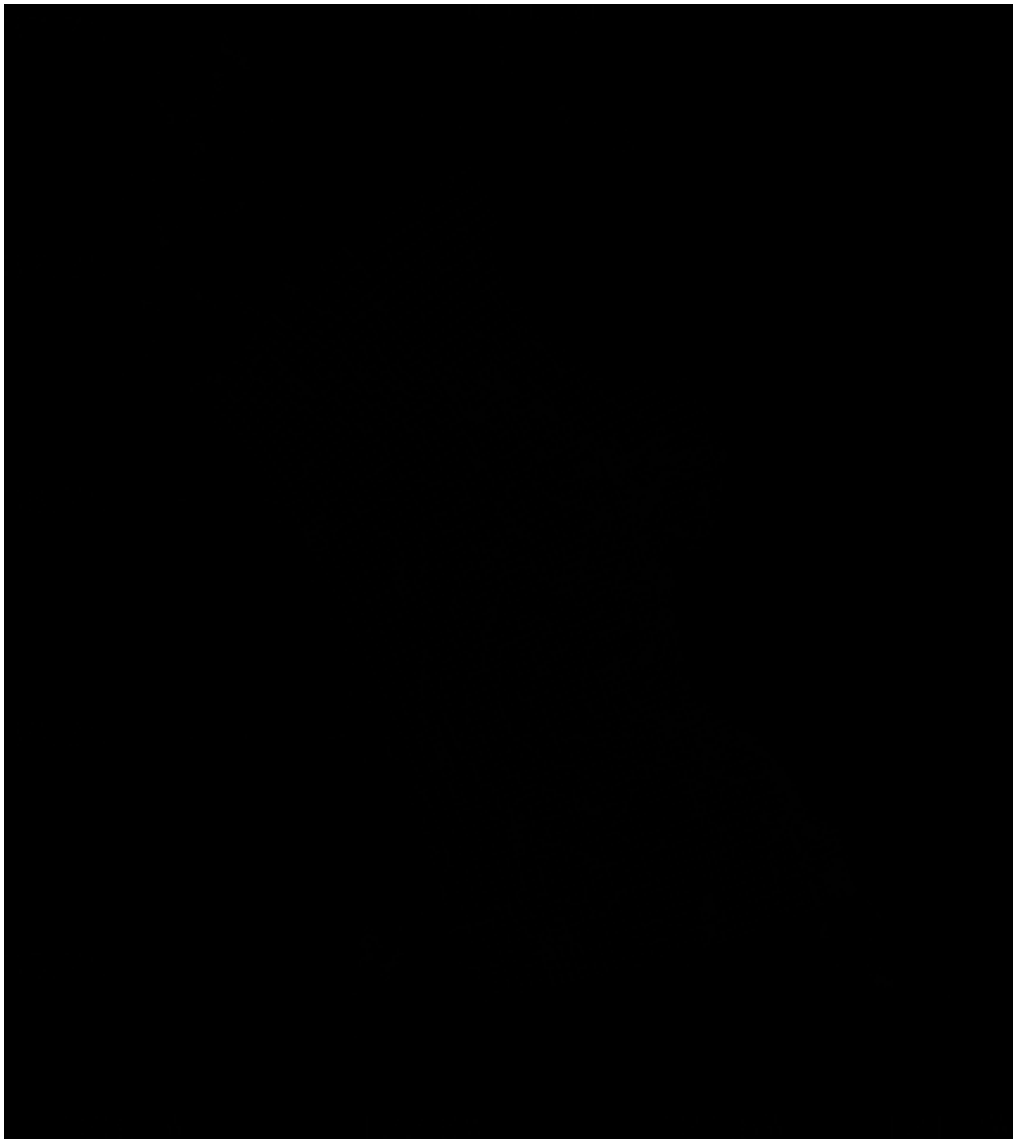
POM

Princeton Ocean Model

This is a **3-dimensional primitive equation** ocean circulation model. It uses σ-coordinates in the vertical (percentage of depth). NAVO cold starts its POM runs every day using MODAS temperature, salinity and geostrophic velocity fields to initialize, and may refer to it as MODAS/POM. In present implementation, **includes wind forcing (usually COAMPS), but no tidal or surface heat flux forcing**. I think it relaxes to climatology on the open boundaries.

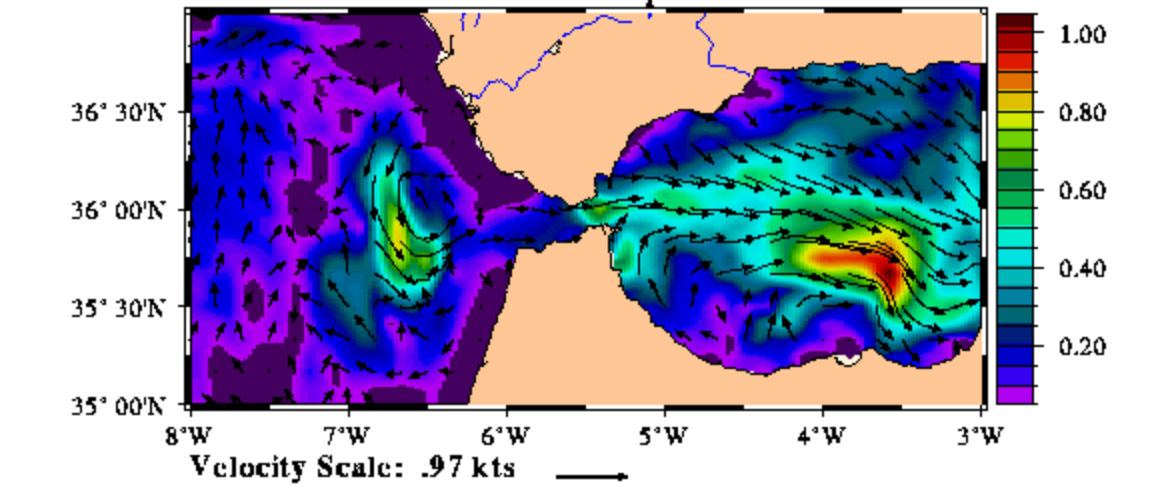
P.E. models include baroclinic pressure gradients,

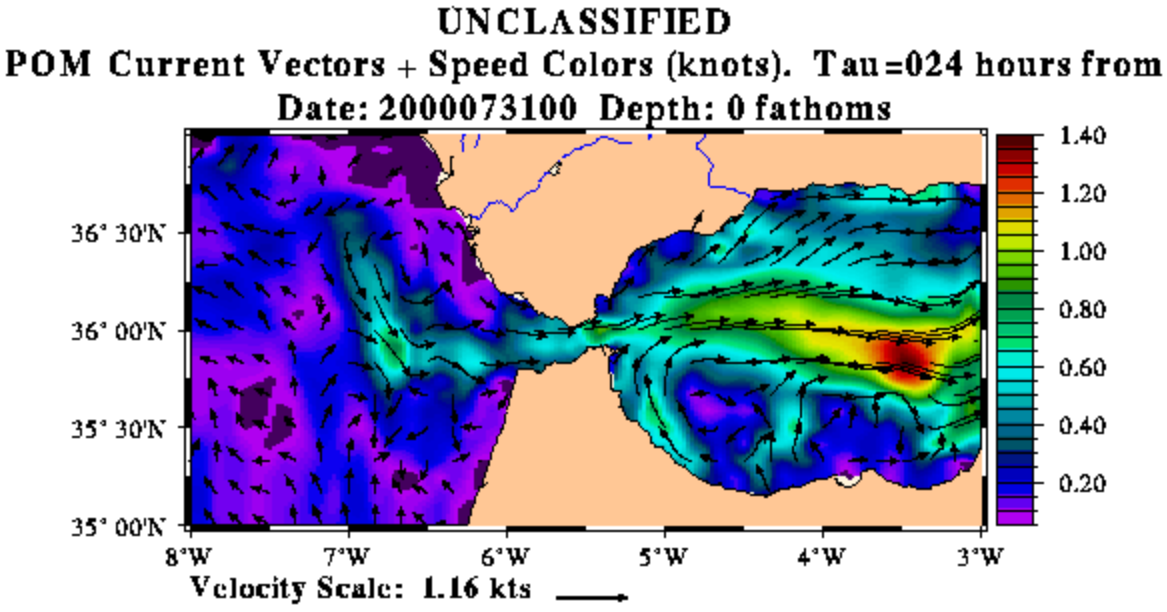
Cartesian Grid



- Updates once per day.
- 24 and 48 h forecasts.
- Currents, and currents over temperature, at 0 and 5 fm displayed (not all update properly) for Gulf of Cadiz
- Critical depth, shallow sound channel axis, deep sound channel axis, depth excess, mixed layer depth, sonic layer depth, and sea surface temperature are output.
- Products may be output in graphical, ArcView (for REACTS), EOF-compacted, NetCDF or other

POM


UNCLASSIFIED
POM Current Vectors + Speed Colors (knots). Tau=000 hours from
Date: 2000073100 Depth: 0 fathoms
36° 30'N
36° 00'N
35° 30'N
35° 00'N
8°W
7°W
6°W
5°W
4°W
3°W
1.00
0.80
0.60
0.40
0.20
Velocity Scale: .97 kts
Distribution authorized to DOD, DOD contractors and Spain only;
Critical Technology, 1 April 1999. Other requests shall be
referred to the Commanding Officer, Naval Oceanographic Office.


UNCLASSIFIED
POM Current Vectors + Speed Colors (knots). Tau=024 hours from
Date: 2000073100 Depth: 0 fathoms
36° 30'N
36° 00'N
35° 30'N
35° 00'N
8°W
7°W
6°W
5°W
4°W
3°W
1.40
1.20
1.00
0.80
0.60
0.40
0.20
Velocity Scale: 1.16 kts
Distribution authorized to DOD, DOD contractors and Spain only;
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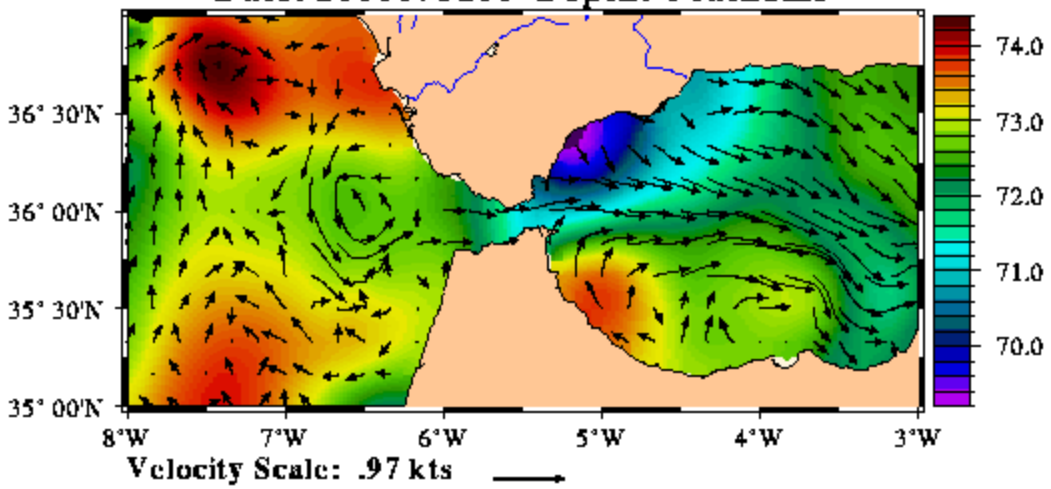
referred to the Commanding Officer, Naval Oceanographic Office.

UNCLASSIFIED

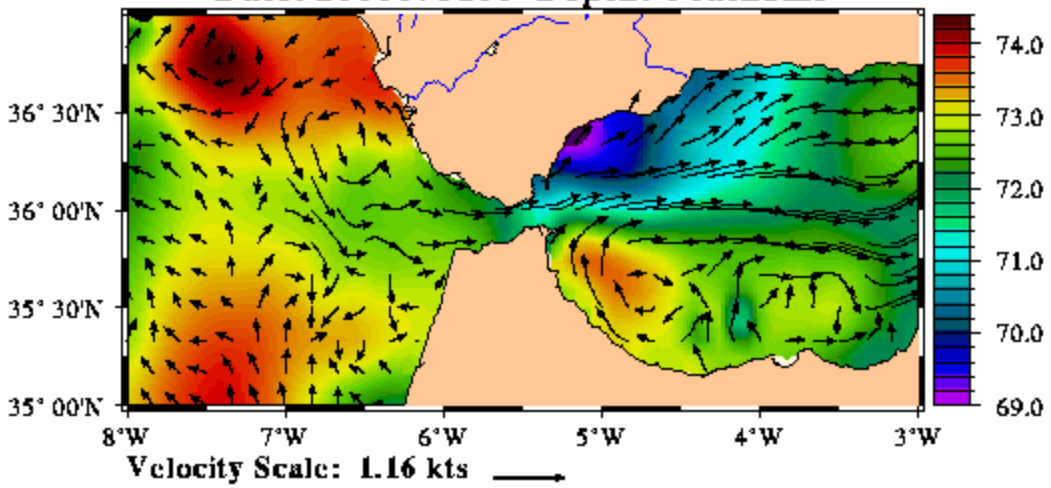
POM Current (knots) over Temp (Deg F) Tau=000 hours from Date: 2000073100 Depth: 0 fathoms



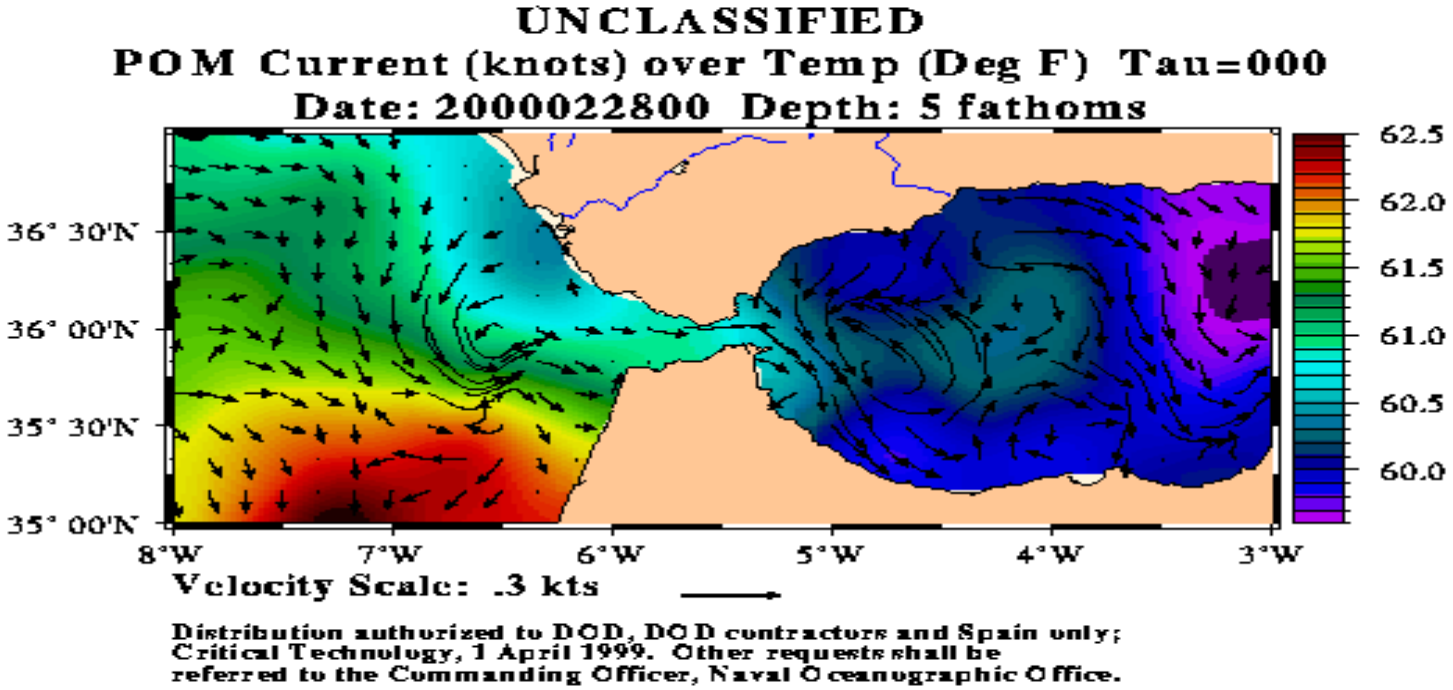
Velocity Scale: .97 kts

UNCLASSIFIED

POM Current (knots) over Temp (Deg F) Tau=024 hours from Date: 2000073100 Depth: 0 fathoms



Velocity Scale: 1.16 kts



SWAFS

Shallow Water Analysis and Forecast System

This is a **3-dimensional primitive equation** ocean circulation model based on the Princeton Ocean Model. It includes vertically and horizontally varying temperature and salinity, and **has wind, surface heat flux, and tidal forcing**, based on the astronomical tide generating forces and Kantha's tide model. Uses an optimal interpolation scheme to assimilate MC-SST, and temperature and salinity profile data. I believe each day's run starts with the output from the previous day's run.

•Running in Mediterranean (with exchange through Straits of Gibraltar and the Dardanelles prescribed) with 10 km spatial resolution.

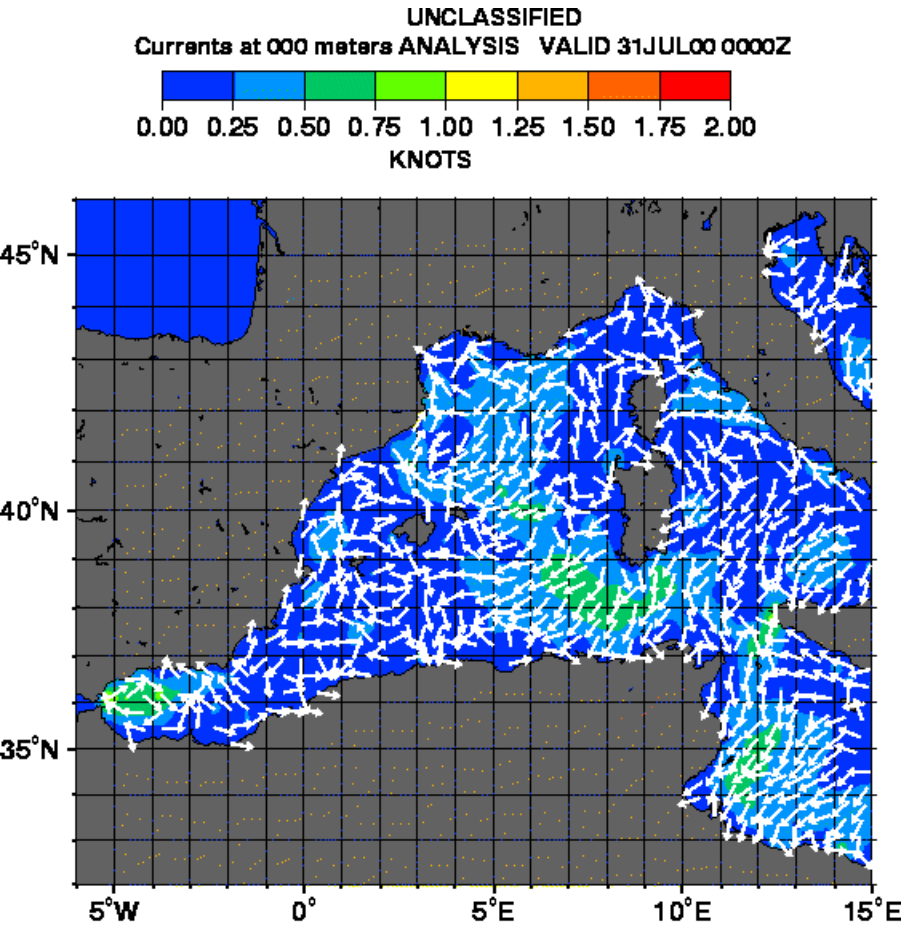
• Updates once per day.

•27 km COAMPS winds, surface heat flux, and tidal forcing.

• NAVO outputs only current speed and direction.

•Various levels, time steps, and geographic domains can be displayed. In Med, 48 hr forecasts at 12 hr or 2 hr 24 min time steps, for 0 and 10 m surfaces

SWAFS



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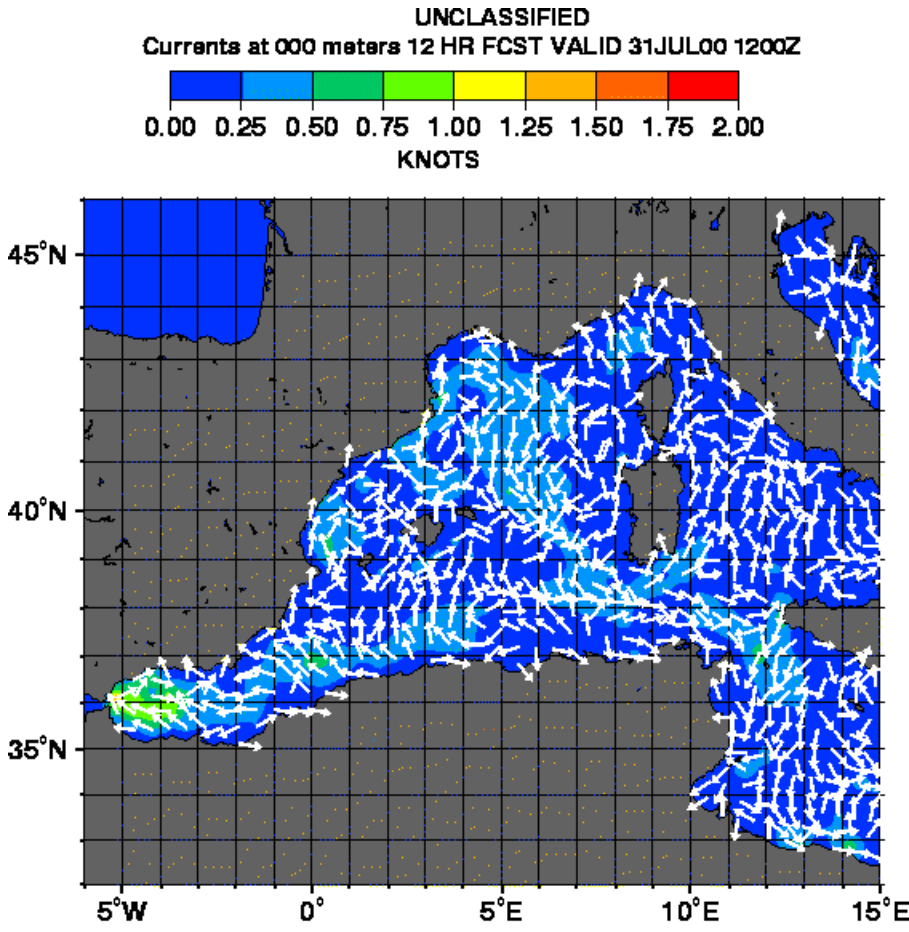
Other requests must be referred to the Commanding Officer,
Naval Oceanographic Office.



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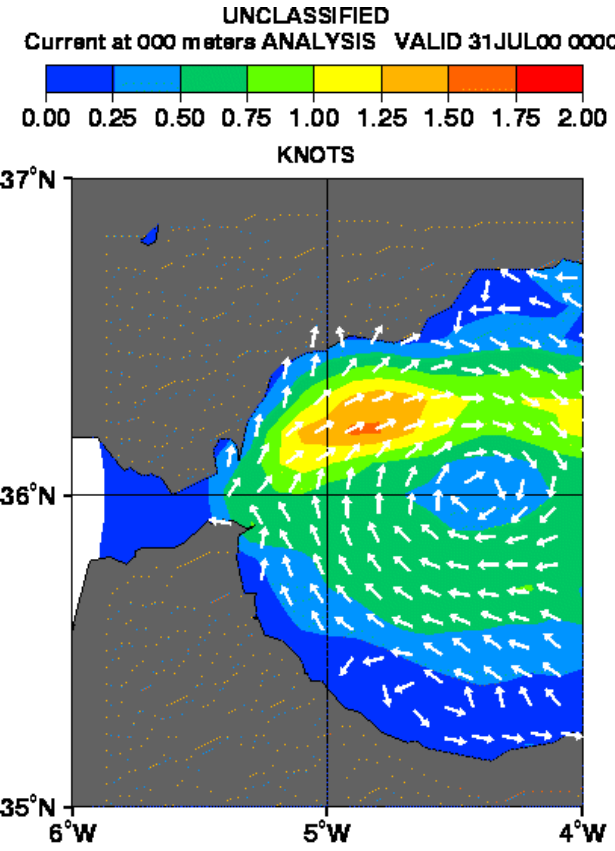
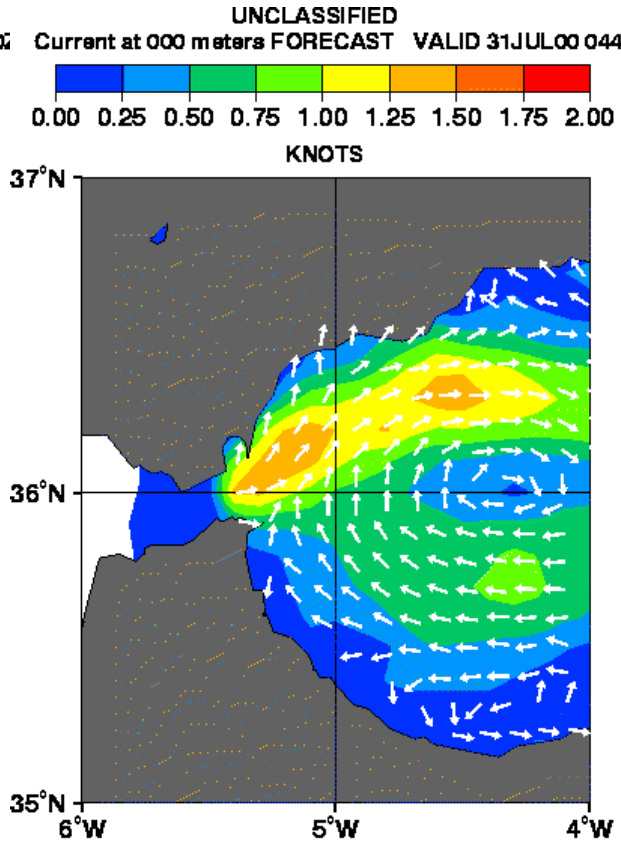
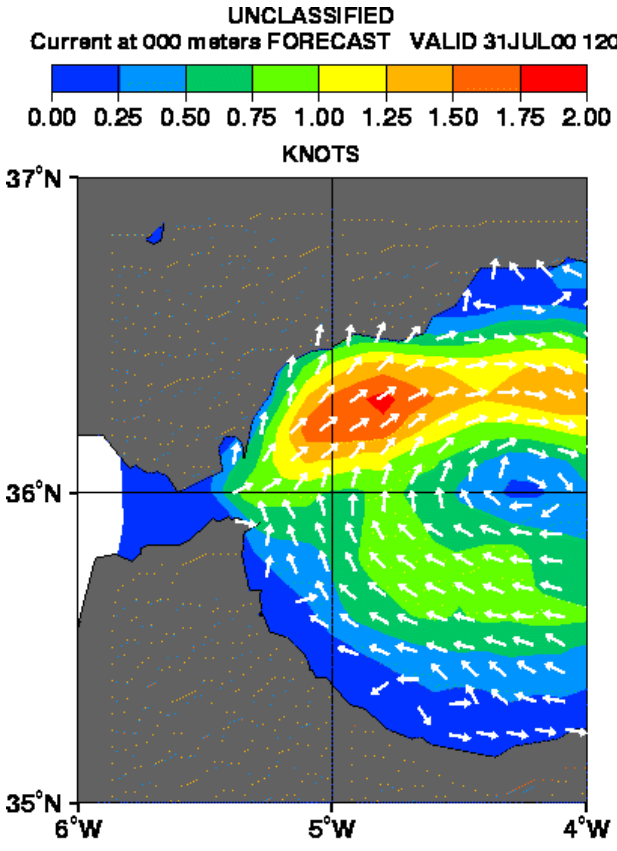
SWAFS



Shallow Water Analysis & Forecast System
Naval Oceanographic Office



Shallow Water Analysis & Forecast System
Naval Oceanographic Office



Shallow Water Analysis & Forecast System
Naval Oceanographic Office

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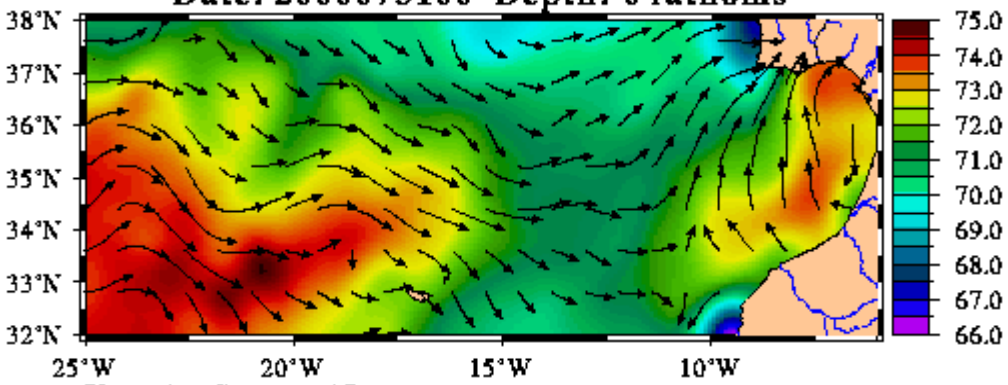
Velocity Vectors (knots) over Temperature (Deg F)

Date: 2000073100 Depth: 0 fathoms



Velocity Scale: .15 kts

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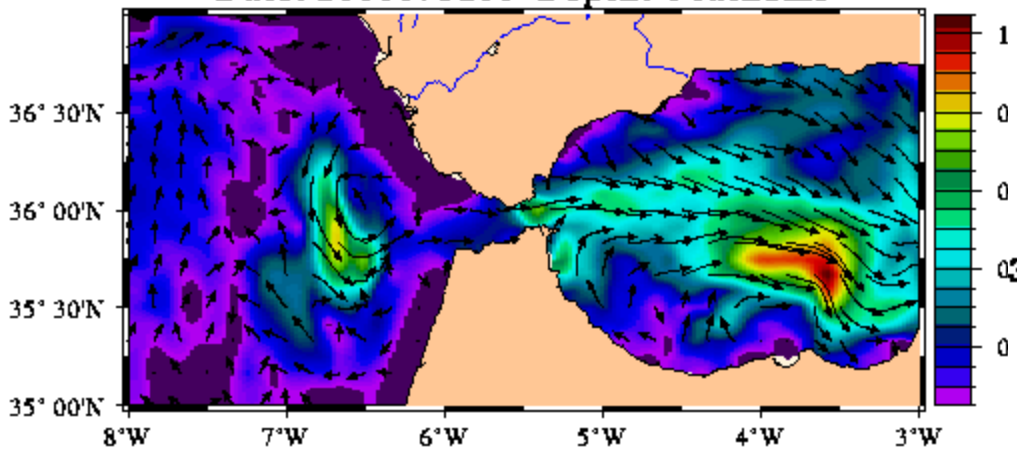
POM Current Vectors + Speed Colors (knots). Tau=000 hours

Date: 2000073100 Depth: 0 fathoms



Velocity Scale: .97 kts

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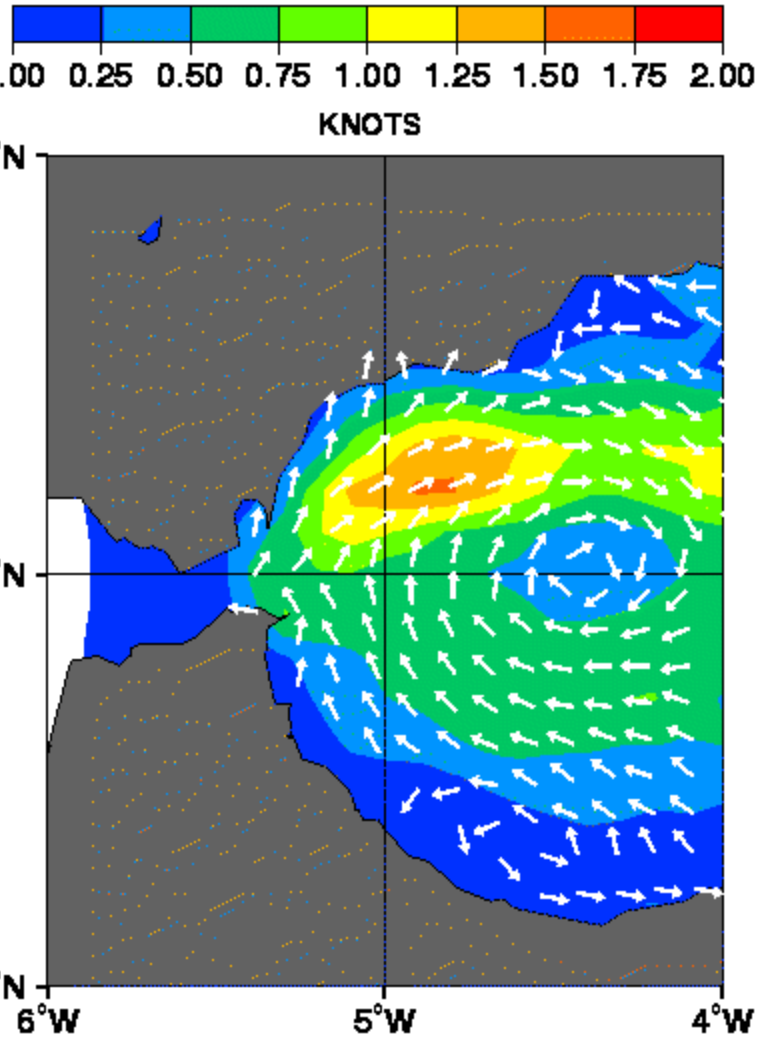
Current at 000 meters ANALYSIS VALID 31JUL00 0000Z



Shallow Water Analysis & Forecast System
Naval Oceanographic Office

SDOM

Simulated Drift Object Model

This model **simulates how a semi-submerged object at the surface would drift**. A handful of initial positions are used. It **can be driven by currents from any of the circulation models**. If driven by SWAFS, it includes tidal currents, if driven by POM, it does not. The intersection of the red and blue lines indicates the initial position of the object (it is the same at the start of every run). The hindcast shows drift along the red line from the free end toward the initial position, the forecast shows drift along the blue line from the initial position toward the free end. Moving along the red line from the initial position goes

SDOM

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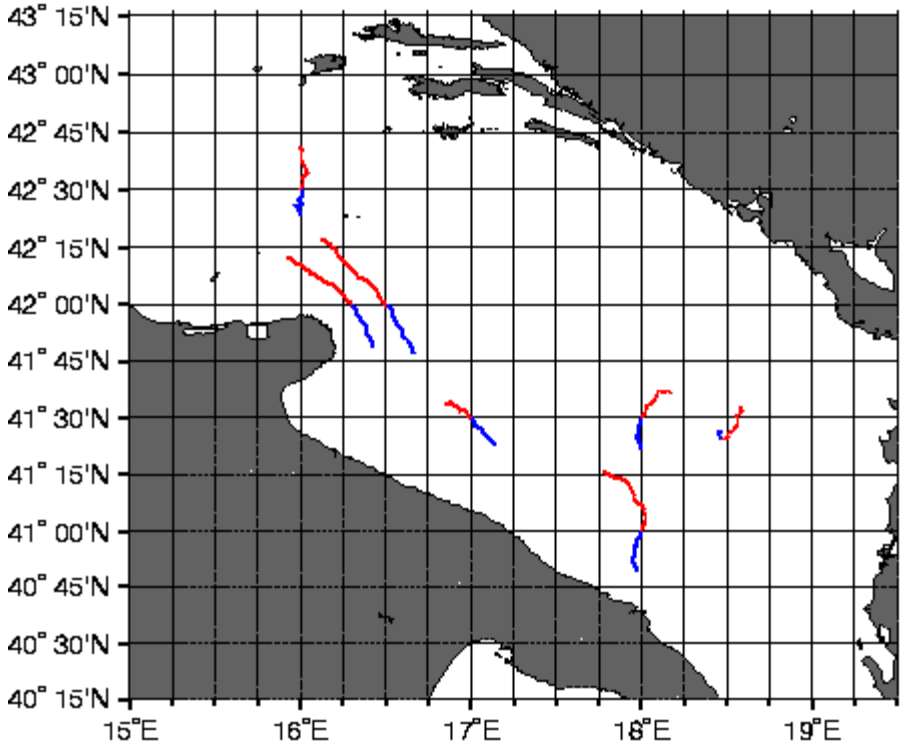
Drift objects plot, 48 hr forecast, 72 hr hindcast VALID 31JUL00 0000Z

RED :Hindcast BLUE :Forecast



Shallow Water Analysis & Forecast System Nest

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Releasable to NATO - Condition of Release

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Product Information
Adriatic Sea Model Simulated Drift Object for SWAFS Based Object Drift-South Adriatic

Product Point of Contact: WSC Watch Floor Supervisor

- DSN Phone Number: 485-5176
- Commercial Number: 228-688-5176

Product Update Cycle: 24 Hours

Typical File Size in KBytes: 17

Level-of-Confidence: This product appears to have operational value but is beyond the control of NMOC to ensure the quality of the underlying data and/or availability of product.

Additional Information:

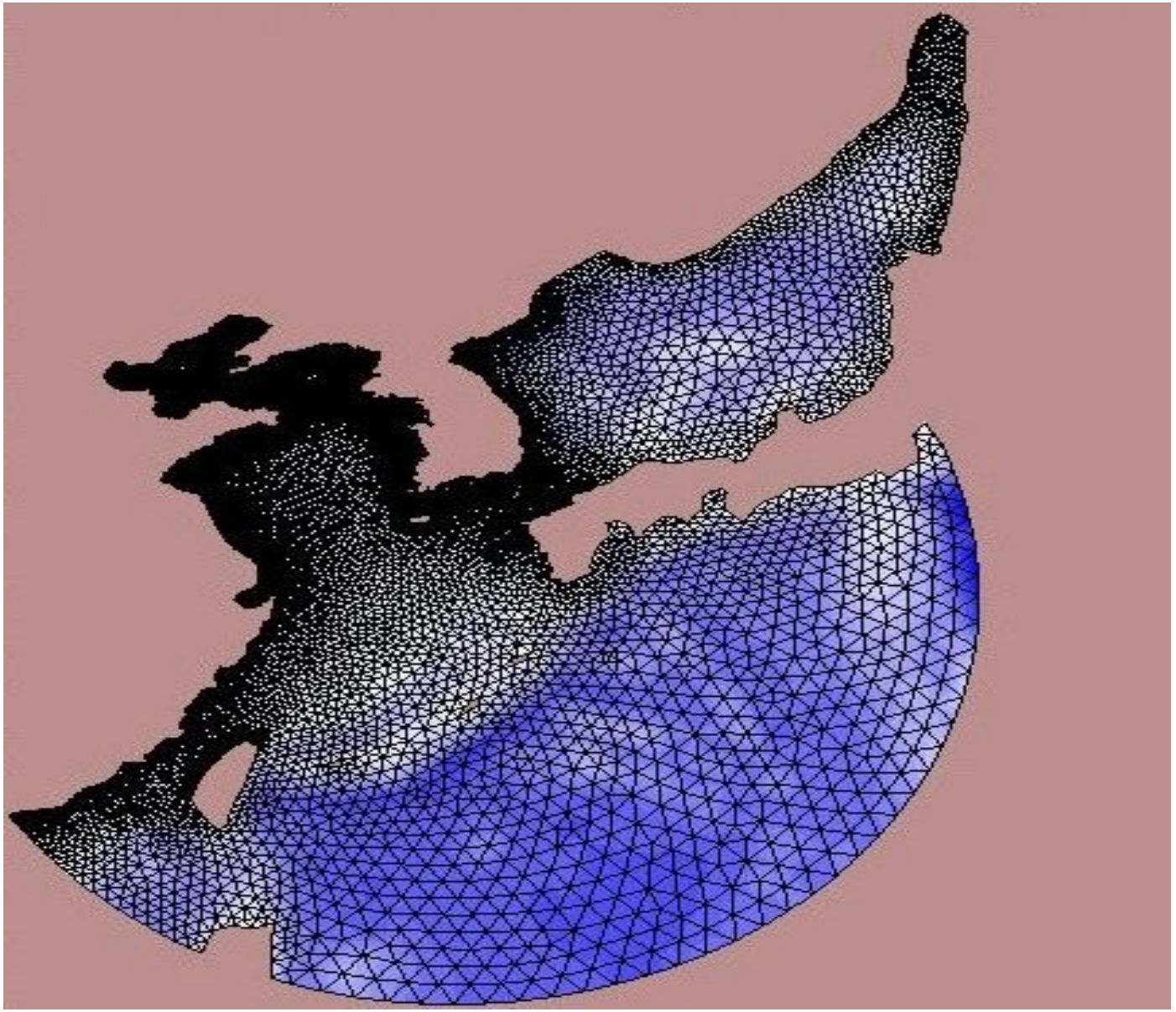
1. Surface Currents used as input are produced by a SWAFS nested model with a 3.3 km. x 2.5 km resolution.
2. Temporal resolution of currents and winds is 1 hour.
3. Semisubmerged objects drift program produces drifting objects positions at 1 hour interval.

AdCirc

Advanced Circulation

This is a **two-dimensional barotropic** circulation model, i.e. all variables are uniform in the vertical and it **can not reproduce currents forced by density gradients**. It includes both **tidal forcing** (based on the astronomical tide generating forces and Grenoble tidal model) and spatially- and temporally-varying **wind forcing**. I do not think it assimilates any data. It runs on a **finite element grid**, so has variable spatial resolution - generally from a few 10's of meters to several kilometers. This model is used to forecast sea level and currents in coastal areas. While sea

FINITE ELEMENT GRID

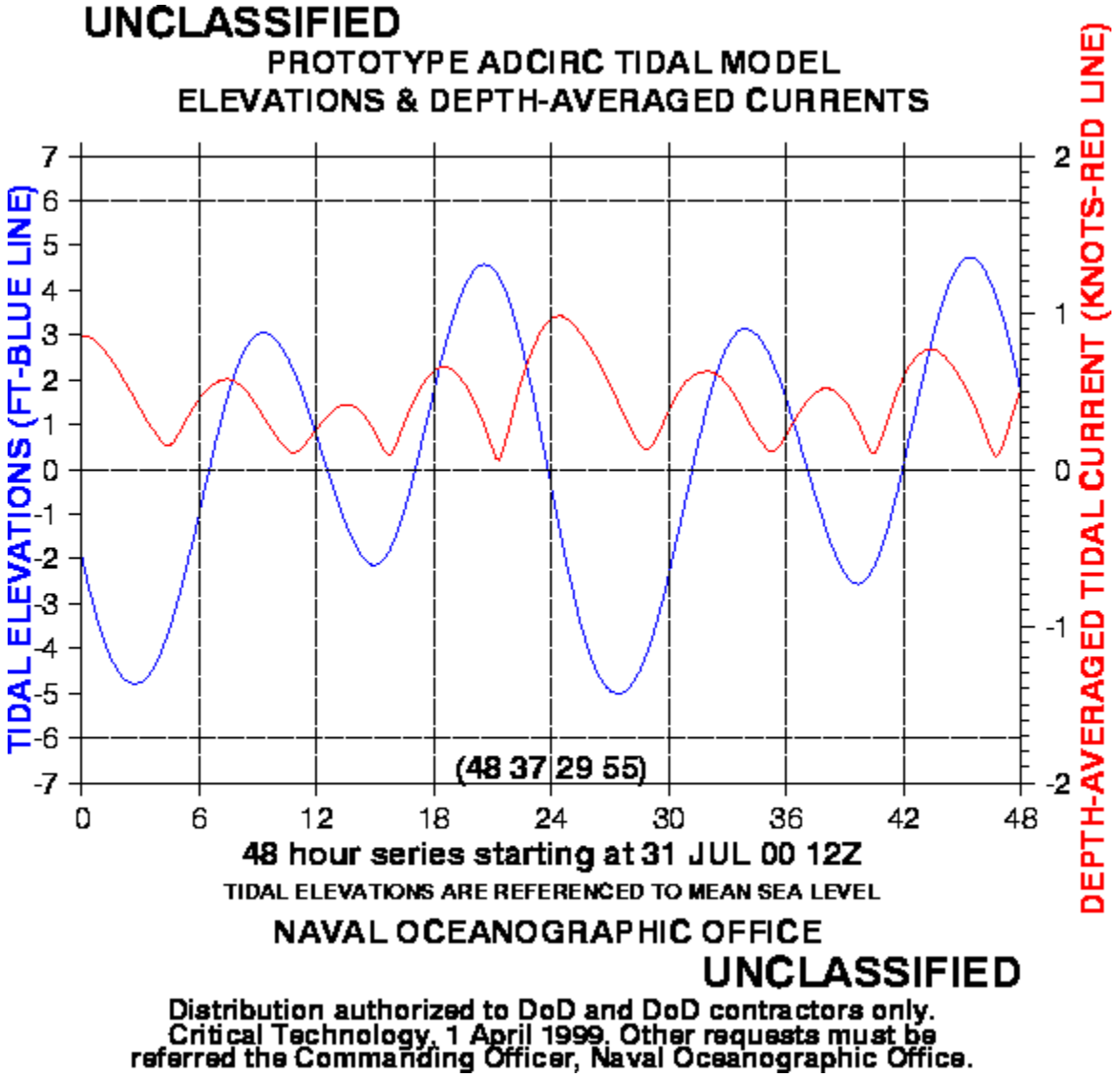


No AdCirc currently running in NEMOC's AOR.

Following example is from Shatt Al Arab.

- Spatial resolution: variable
- Forcing: 27 km COAMPS_SW_ASIA winds and atmospheric pressure ; and tidal forcing
- Output available through MVL: sea level relative to MSL (mean sea level); depth-averaged current speed and direction
- Temporal resolution and forecast duration: 30 min. out to 48 h
- Product update cycle: 12 h

AdCirc


UNCLASSIFIED
PROTOTYPE ADCIRC TIDAL MODEL
ELEVATIONS & DEPTH-AVERAGED CURRENTS
TIDAL ELEVATIONS (FT-BLUE LINE)
DEPTH-AVERAGED TIDAL CURRENT (KNOTS-RED LINE)
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
2
1
0
-1
-2
0
6
12
18
24
30
36
42
48
(48 37 29 55)
48 hour series starting at 31 JUL 00 12Z
TIDAL ELEVATIONS ARE REFERENCED TO MEAN SEA LEVEL
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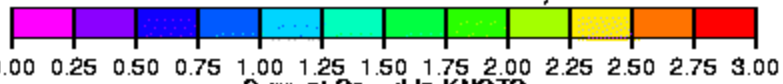
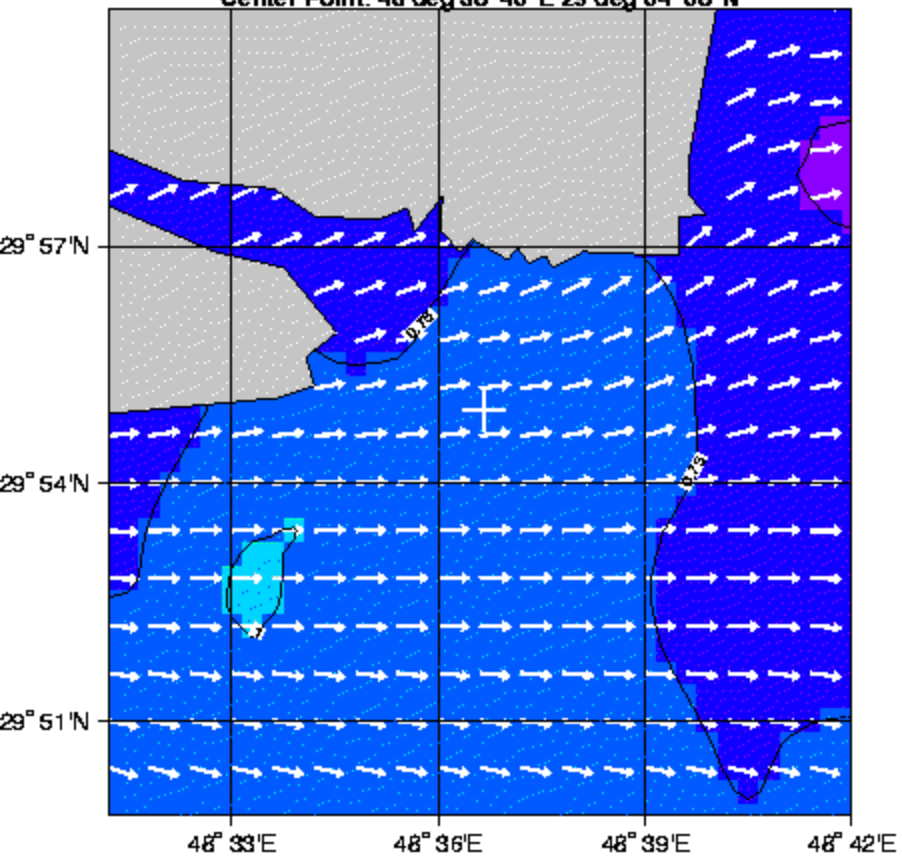
UNCLASSIFIED
Tidal Forecast VALID: 31JUL00, 1200Z



Current Speed In KNOTS

White cross represents location chosen to generate time series plot.

Center Point: 48 deg 36' 40"E 29 deg 54' 66"N



Prototype Advanced Circulaton Tidal Model (with wind driven currents)
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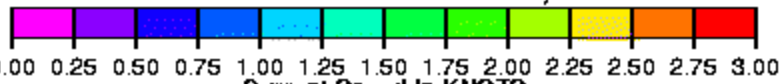
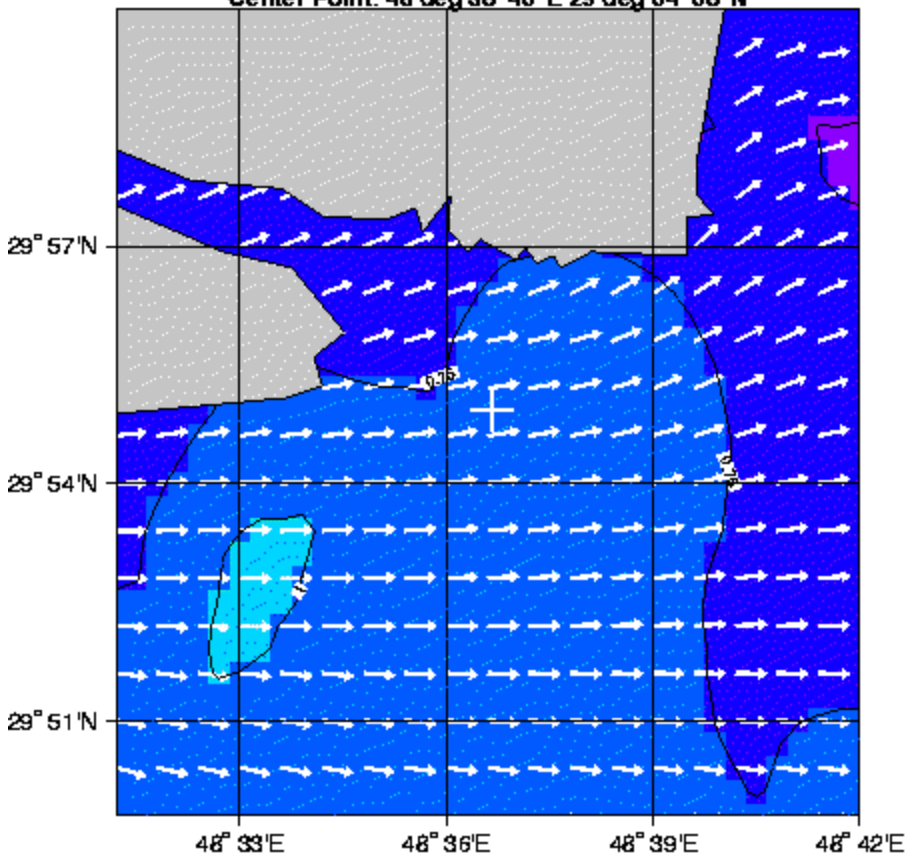
UNCLASSIFIED
Tidal Forecast VALID: 31JUL00, 1230Z



Current Speed In KNOTS

White cross represents location chosen to generate time series plot.

Center Point: 48 deg 36' 40"E 29 deg 54' 66"N

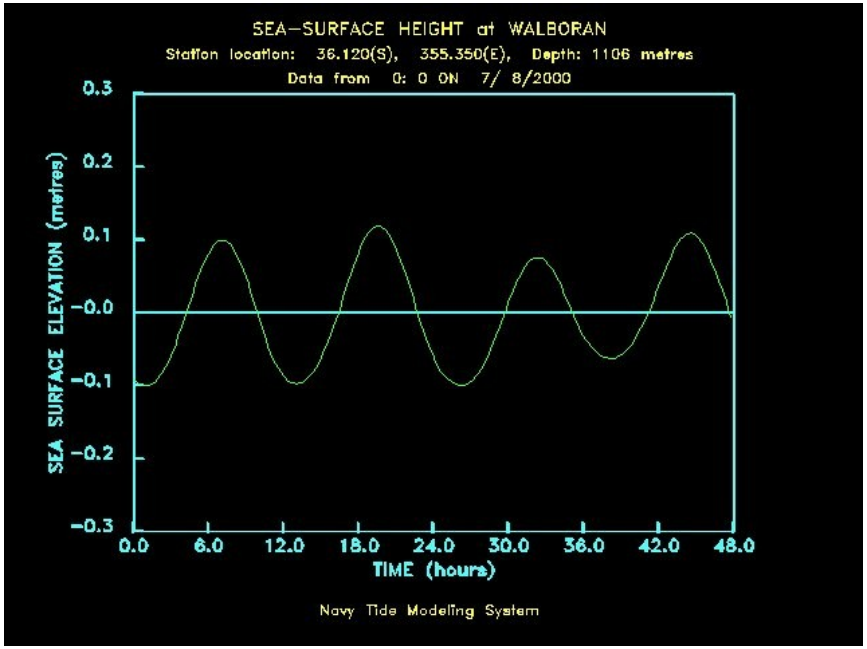


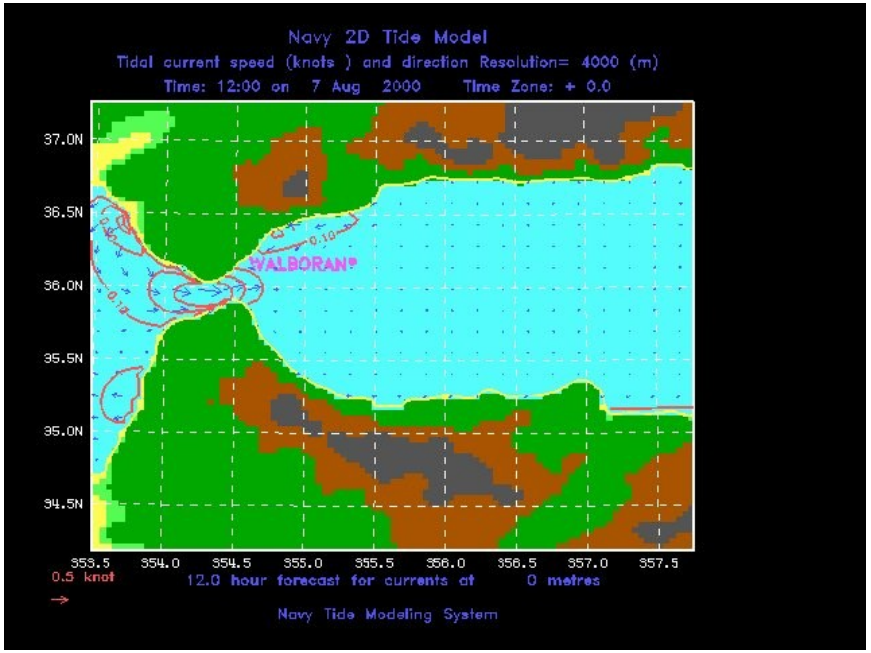
Prototype Advanced Circulaton Tidal Model (with wind driven currents)
NAVAL OCEANOGRAPHIC OFFICE
UNCLASSIFIED
Distribution authorized to DoD and DoD contractors only;
Critical Technology, 1 April 1999. Other requests must be referred
to the Commanding Officer, Naval Oceanographic Office.

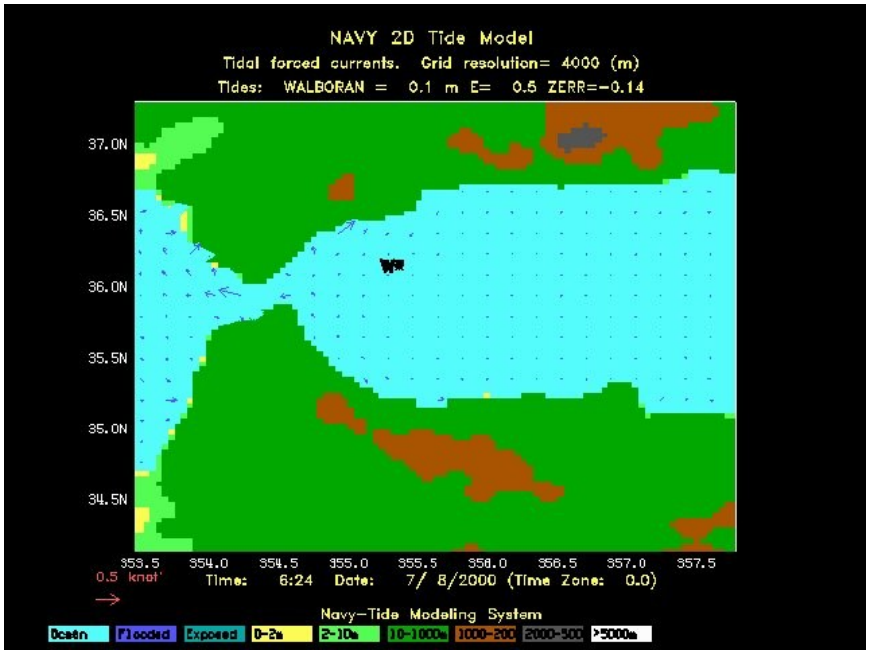
PC-TIDES

(Navy Relocatable Tide/Surge Modeling System)

Uses shallow water (**barotropic**) equations (i.e. **no contribution to pressure gradient from density field**). Normally run in 2-d mode. When run in 3-d mode, will get some vertical structure due to bottom friction. **Currently runs with tide forcing only**. Wind forcing to be added in future. Uses global tide model for boundary conditions. Uses Cartesian grid. Can nest grids within each other. Can output horizontal pictures and time-series


SEA–SURFACE HEIGHT at WALBORAN
Station location: 36.120(S), 355.350(E), Depth: 1106 metres
Data from 0: 0 ON 7/ 8/2000
SEA SURFACE ELEVATION (metres)
0.3
0.2
0.1
−0.0
−0.1
−0.2
−0.3
0.0
6.0
12.0
18.0
24.0
30.0
36.0
42.0
48.0
TIME (hours)
Navy Tide Modeling System

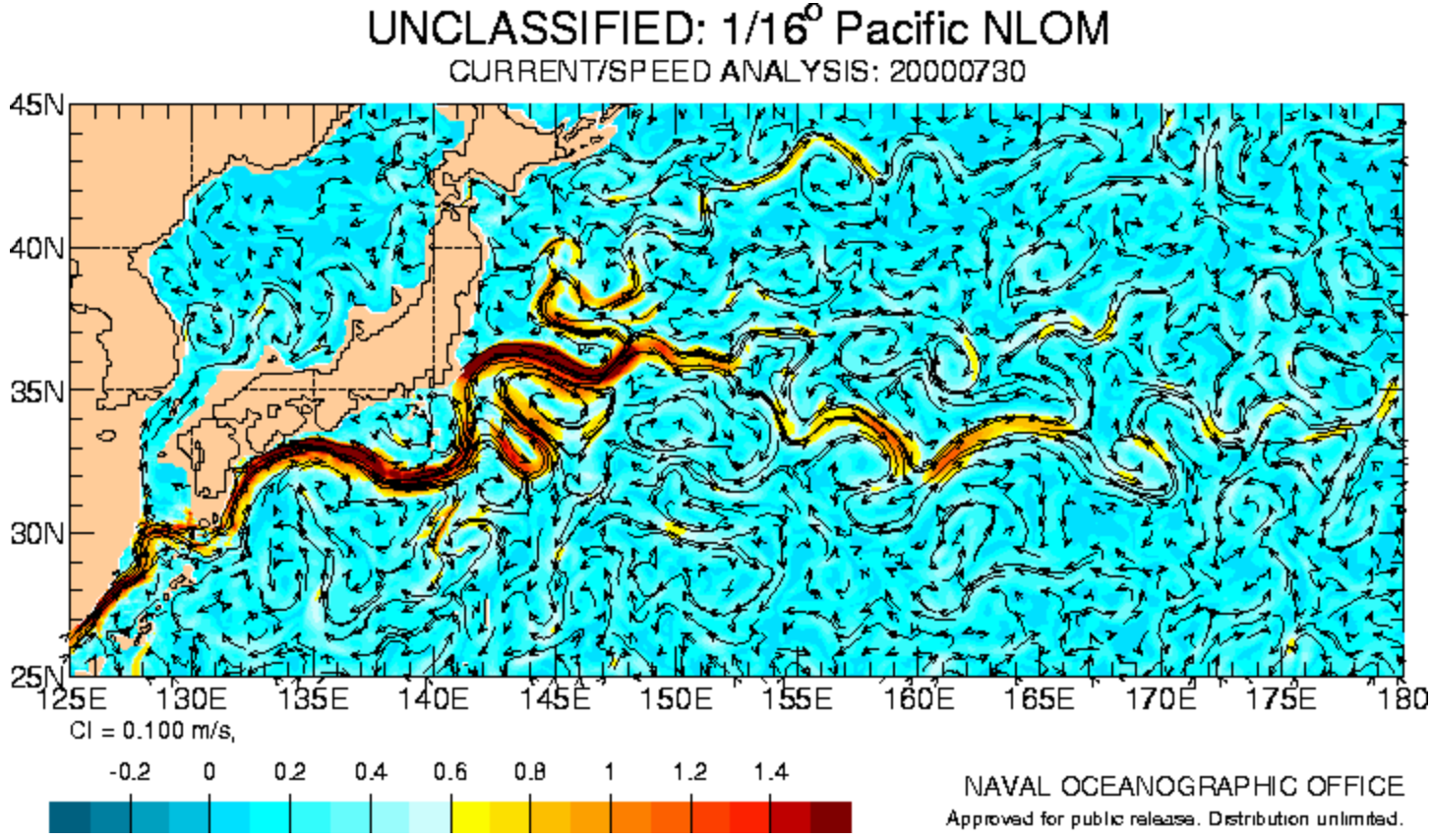

Navy 2D Tide Model
Tidal current speed (knots) and direction Resolution= 4000 (m)
Time: 12:00 on 7 Aug 2000 Time Zone: + 0.0
37.0N
36.5N
36.0N
35.5N
35.0N
34.5N
WALBORAN
353.5
354.0
354.5
355.0
355.5
356.0
356.5
357.0
357.5
0.5 knot
12.0 hour forecast for currents at 0 metres
Navy Tide Modeling System


NAVY 2D Tide Model
Tidal forced currents. Grid resolution= 4000 (m)
Tides: WALBORAN = 0.1 m E= 0.5 ZERR=-0.14
37.0N
36.5N
36.0N
35.5N
35.0N
34.5N
353.5
354.0
354.5
355.0
355.5
356.0
356.5
357.0
357.5
0.5 knot
Time: 6:24 Date: 7/ 8/2000 (Time Zone: 0.0)
Navy–Tide Modeling System
Ocean
Flooded
Exposed
0-2m
2-10m
10-1000m
1000-200
2000-500
>5000m

NLOM
Navy Layered Ocean Model

- Primitive equation model
- Used as large-scale, rather than regional coastal, model
- Vertical coordinate is density
- Uses 6 layers, so vertical resolution is limited
- Incorporates topography
- Forced by NOGAPS winds stress and heat flux
- Assimilates satellite SSH

NLOM



Speed
(m/s)

GFMPL - NAVSAR

Naval Search and Rescue

One-dimensional mixed-layer model forced with user-input wind and currents. Be sure whether directions are to be entered as “towards” or “from”.

Model Characteristics

	MODAS	POM	SWAFS	NLOM	AdCirc	PC-Tides	GFMPL - SAR
Time-varying	No	Yes	Yes	Yes	Yes	Yes	No
3-d	Yes	Yes	Yes	Yes	No	No	No (1-d)
Tides	No	Not at this time	Yes	No	Yes	Yes	No
Winds	No	Yes	Yes	Yes	Yes	Not at this time	Yes
Surf. ht. flux							
Data assim.							
Nesting							

A few tips:

Be sure you know what variable you're looking at.

Be sure you know what depth level you're looking at:

fm, m, ft.

Check the units: m/s, cm/s, kts

Scenarios

(assume all models are available)

- Ex CO is sailing from MS to Bahamas then on to Chesapeake Bay over next month. He wants guidance on position of Loop Current and Gulf Stream.

MODAS

NLO
M

POM

- Low flying helicopter crashes in high winds over deep water in middle of Mediterranean. Provide guidance on surface drift.

GFMPL-SAR

SDOM

- SEALS will be swimming 2 km to shore from RHIB tomorrow at 0600. Predict surface currents (offshore of the surf zone).

AdCirc

PC-TIDES